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An overview on *Parkia biglobosa* starch digestibility, health benefits and some applications

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ABSTRACT: African locust bean (*Parkia biglobosa*) tree is an important food tree and source of starch from its seeds. The purpose of this work is to address the African locust bean starch extraction, in vitro digestibility, health benefits and use of its resistant starch-rich powder in application of bread making reported in the available literature. Optimized method of starch extraction from *P. biglobosa* seed was highlighted. In vitro digestibility of different *Parkia* starch obtained are of nutritional and health benefit grades. Based on the results in the literature the sensory analysis of the different portion of *Parkia* resistant starch-rich powder in application of bread making reported to have shown significant acceptability by the consumers in comparison with full wheat bread. This overview on *Parkia* starch could be a channel for food developers to rethink of using this research results in bringing up a nutritionally health benefits functional food products, especially in developing countries where malnutrition is prevalent.

Keywords: *Parkia biglobosa*; Starch; Resistant starch; Physicochemical properties; Functional food.

1. INTRODUCTION

The tree *Parkia biglobosa* known as African locust bean is a source of livelihood for both human and livestock, and it is very important to rural population. It is also source revenue in the sub-Saharan region. When it comes to the processing of the seeds into a fermented product called dawdawa or iru a popular food seasoning that is rich in vitamin B2 and protein, thus, every part of the plant species is important and valuable as fodder or food [1, 2]. In medicines, *P. biglobosa* is used against bronchitis, pneumonia, diarrhea, violent colic, vomiting, sores and ulcers. The root of *P. biglobosa* when combined with leaves can be used in lotions for sore eyes, they treat diseases such as dental carries and conjunctivitis, cough, bronchitis, amoebiasis and pile [3]. In addition, popular diseases in the plant habitat like malaria and stomach disorders are also cured by the plant and more other illness. Moreover, poultry lice, trypanosomes and mouth ulcers of ruminants are also treated illness of farm animals by the plant. Apart the use of pods and husks as feed for livestock; it is also used in traditional ceremonies [2, 4].

Chemical and nutritional composition of *P. biglobosa* seeds have shown that it is rich in protein, starch, soluble sugars, lipids, and ascorbic acid [5, 6]. Furthermore, apart the fruit the bark and root of the tree are also used in traditional medicine [3, 4]. In addition, the seeds can be roasted for the production of a tea, like infusion (called Soudan Coffee) or fermented to be used as spicy seasoning widely used in sauces and sometimes processed as stock cube. The incredible part of African locust bean is its seed, which is of multipurpose usage from food and nonfood application; indeed, the seed is a good source and useful ingredients for consumption [7]. This work aims to highlight the method of *P. biglobosa* starch extraction, digestibility, health benefits and use of resistant starch-rich powder from *Parkia* in application of bread making as reported in the literature.

2. WHAT IS PARKIA BIGLOBOSA?

The African locust bean tree, *P. biglobosa* is a perennial tree legume which belongs to the sub-family Mimosoideae and family Leguminosae (now family Fabaceae). The savannah region of West Africa up to the southern edge of the Sahel area (13°) constitutes its habitat [7, 8]. Popularly called the “African locust bean tree”, they are known to occur in a diversity of agro ecological zones from tropical rainforest where the rain is high to the arid zone where it is low. The height ranges from 7-30 m. The tree is large crown and wide spreads with low branches; and the leaves of *Parkia* are dark green, bipinnate, alternate and about 1.5-8 mm x 8-30 mm in size with about 13-60 pairs of leaflets of distinct venation on a long rachis. The colors of African locust bean pods when matured are dark brown to pink brown; they are up to 2 cm wide and 45 cm long. It can be found up to 30 seeds in one pod embedded in a yellow pericarp. The seeds have a hard test with an average weight of 0.26 g and relatively large [9].

P. biglobosa has a wide distribution ranging across the Sudan and Guinea savanna ecological zones. *P. biglobosa* tree has the capacity to withstand drought conditions because of its deep tap root system and an ability to restrict transpiration. *P. biglobosa* tree is an important food tree and plays a very vital role in the rural economics of West African countries: Senegal, the Gambia, Guinea Bissau, Guinea, Sierra Leone, Mali, Côte d’Ivoire, Burkina Faso, Ghana, Togo, Benin, Niger, Nigeria; West-Central Tropical Africa: Cameroon; Central African Republic and Northeast Tropical Africa: Chad; Sudan [10, 11].

3. STARCH

Glucose units joined by glycosidic bonds are constituents of carbohydrate called amylose or starch, and they are energy store for all green plants. It is also the main store of carbohydrate and energy in plants. Starch is found in semi-crystalline granules form in most tissues, though more abundant in storage tissues such as tubers, seeds and roots. In general, the granules are almost entirely composed of two glucose polymers, amylopectin and amylose, with small amounts of phosphorus, lipids and minerals [12, 13]. Starch happened to be the most abundant carbohydrate in the human diet and is much more common in large amounts in people’s staple foods as corn, wheat and potatoes, cassava and rice. Pure starch is insoluble in alcohol or cold water, it is tasteless, white and odorless powder. The linear and helical amylose and the branched amylopectin are two types of molecules that constitute the starch. Generally, it contains 75 to 80% amylopectin and 20 to 25% amylose by weight depending on the plant [14]. In food processing starch is transformed to produce various sugars. Starch is used in various industries as thickener, stiffening or gluten agent by just dissolving it in warm water to give paste. Furthermore, starch is used as adhesive in the papermaking process of the biggest non-food industries.

African locust bean or *P. biglobosa* seeds are good sources of protein, fat and calcium, but contain a non-toxic oil of variable composition. Some sources indicate arachidic acid as the most abundant fatty acid, accompanied by behenic, stearic, palmitic and linoleic acids; other sources mention oleic acid as the most important component (35-50%) with, in addition, equal amounts of behenic, oleic, palmitic and stearic acids [1]. However, qualitative determination of the chemical and nutritional composition of *P. biglobosa* seeds informed of good source of starch, soluble sugars, ascorbic acid, lipids and protein [15]. Moisture content 6%, protein 28.4%, total ash 3%, amylose: amylopectin ratio 23:80%, phosphorus (mg/100 g) 188.6, calcium (mg/100 g) 45.3, iron (mg/100 g) 65.6 [6].

4. AFRICAN LOCUST BEAN AND ITS EXTRACTION

Historically, the starch of *Cattails bullrushes* from its rhizomes as flour have been produced back 30,000 years ago in Europe using stones as grinding material [16]. Chinese used rice starch to treat paper surface since 700 AD onwards, while the ancient Egypt extracted wheat pure starch paste as possibly to glue papyrus [17]. The growing demand for food, due to increasing global population and increase in disposable income levels, and the demand for starch for both food and non-food starch products is growing day by day [18-20]. The world economy through the global increase in food prices is affected as the increasing dependence of more industries on food sources of starch such as maize, yam, cassava, wheat for raw materials. Thus, the importance of exploring discarded materials like seeds of *P. biglobosa* as sources of starch for industrial application is today a reality [21]. Starch found multiples and variant usages in industries as the most widely used biomaterials in the food, plastic, textile, adhesives, paper, cosmetics and pharmaceutical industries. The diverse industrial usage of starch is due to its availability at low cost, inherent excellent physicochemical properties, high caloric value; thus, these make it easy for modification to other derivatives. The starch versatility in industrial applications depends a lot with the plants source leading to biological origin that will vary its physicochemical properties [22]. The world diversity of plant species is an important source of starch for various purposes; unfortunately, they are yet to be fully explored like that of Africa locust bean (*P. biglobosa*).

Parkia starch extraction by the Sankhon et al. works [21] reported three methods for on optimum yield after the sample preparation. The first method by Adebawale and Lawal [23] was based on 0.5% (w/v) sodium hydroxide solution, followed by the method of Omojola et al. [24] also based on sodium metabisulphite solution (10 L 1.5% w/v) and then the third method based on distilled water [21]. The different methods of *Parkia* starch extraction yields increasingly from methods 1, 2 and 3 respectively. Water usage in method 3 of the *Parkia* starch extraction was reported to give higher proportion of starch yield to protein content which was low [21]. Solvent water in *Parkia* starch extraction minimized use of chemical even though excessive washing is required, exhaustive yield and purity were obtained as reported by Sankhon et al. [21] research. To reach some high starch purity often sodium hydroxide is used. The work of Chanapamokkhot and Thongngam [25] on sorghum starch is comparable to that of Sankhon et al. [21] research on *Parkia* starch obtained.

5. STARCH FRACTIONS AND ITS HEALTH BENEFITS

For nutritional purposes, starch is subdivided into three types: rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) according to in vitro digestibility of it [26, 27]. The RDS fraction cause more rapid increase in blood glucose concentration after ingestion of carbohydrates, known as the amount of starch digested in vitro in the first 20 min of a standard digestion reaction of the mixture [27].

In the same way the RDS was demonstrated to follow similar kinetics in the human digestive system as it was carried out in the rate of starch conversion to sugar [28]. RDS means mainly amorphous starch fractions that occur in high amounts in freshly cooked or baked starchy foods bread, potatoes [29].

The SDS fraction happened to be the slowest digestible fraction though completely in the human small intestine [28]. At no longer than 120 min under standard conditions of substrate and enzyme concentration the SDS is digested which make it second after RDS [27, 30]. The in vivo test revealed that SDS have potential health benefits like stable glucose metabolism, diabetes management, satiety and mental performance [31, 32]. Amorphous starches are the most physical inaccessible, raw starches with A-type or C-type crystalline pattern and B-type starches either in granule form or retrograded form belong to this type.

Any other starch that can not to digested within 120 min in the small intestine is called “resistant starch” (RS) [20, 28], as defined and named by Englyst et al. [27]; and later formally by the European Flair Concerted Action on Resistant Starch (EURESTA) as “starch or products of starch degradation that escapes digestion in the human small intestine of healthy individuals and may be completely or partially fermented in the large intestine as a substrate for the colonic microflora acting as a prebiotic material” [33, 34]. Furthermore, RS is defined as “the sum of starch and degradation products of starch not absorbed in the small intestine of healthy individuals” [35]. RS is classified into four subtypes called RS1, RS2, RS3 and RS4 [27, 36, 37]. RS1 represents starch present in foods with very dense structure such as whole grains and partially milled seeds and in some processed starchy foods and is heat stable in most normal cooking operations [27]. Foods such as boiled rice, pasta, whole-grain bread, maize and legumes are also found to contain RS1 [18]. RS2 is the form which is tightly packed, has a high density and is partially crystalline, preventing enzymatic action. It can be found in foods with uncooked starch such as raw potato, bananas [35, 38], raw cereal flours, dry-baked biscuits and legumes [18]. RS3 is the fraction which forms when there is heat-moisture treatment involved, that is, during cooling of gelatinized starch [30, 38]. Cooling and ageing of the gel cause the reformation of a crystalline structure among the polymers, the phenomenon termed as retrogradation [24, 27]. RS4, on the other hand, is developed after some chemical or thermal treatments to the starch [30], and with the indigestibility usually accounted to substituents or new glycosidic bonds formed by dry heat [39]. Among these four types, RS3 is the most common form in the diet. Furthermore, RS3 is considered the most important because it is generated due to food processing [40] and has a huge potential for use in a wide array of applications in the food industry due to its thermal stability [41]. In addition, RS consumption can help reduce the caloric intake, glycemic response, and concentrations of cholesterol and triglycerides [35]. Recently, people habit of eating and drinking have become major threat to human health in many nations leading to various illnesses like obesity, cardiovascular disease, cancer and diabetes. Etiologically, out of those multi-factorial causes, diet has been identified as one of the most important environmental risk factors for development of such illnesses. Resistant starch can be categorized as a part of dietary fiber. Like soluble fibers, RS also has a number of physiological effects which have been proved to be beneficial for health [29]. Indeed, RS acts largely through its large bowel bacterial fermentation products (short-chain fatty acids, SCFA) but interest is favorable as potential prebiotic as it enhances the fibre content of foodstuffs, particularly those which are low in energy and/or in total carbohydrate content. In addition, RS can lower the energy value and available carbohydrate content of foods. Resistant starch has the potential to accelerate the onset of satiation and to lower the glycemic response, to enhance colonic health [28, 29]. Like soluble fibres, resistant starch can be categorised as such with a number of physiological effects proving with various health benefits (Table 1), depending on methodology and differences in the source, dose and type of RS consumed.

Table 1. Health properties of resistant starches. Sources [33, 34].

Potential health benefits	Probable protective effect
Control of glycaemic and insulinaemic responses	Diabetes, impaired glucose and insulin responses, the metabolic syndrome
Improved bowel health	Colorectal cancer, constipation, inflammatory bowel disease, ulcerative colitis, diverticulitis
Improved blood lipid profile	Lipid metabolism, the metabolic syndrome, cardiovascular disease
Prebiotic and culture protagonist	Colonic health
Increased satiety and reduced energy intake	Obesity
Increased micronutrient absorption	Enhanced mineral absorption, osteoporosis
Adjunct to oral rehydration therapies	Treatment of cholera, chronic diarrhea
Synergistic interactions with other dietary components, e.g. dietary fibres, proteins, lipids	Enhanced bowel health and improved metabolic control
Thermogenesis	Diabetes, obesity

6. IN VITRO DIGESTIBILITY OF *PARKIA* STARCH

Based on the Englyst test, Sanknon et al. [42] reported the percentages of RDS, SDS, and RS in normal *Parkia* starch were of 10.91%, 52.29%, and 33.41%, respectively. In addition this investigation on the mechanism of the formation, properties and molecular structure of the slowly digestible *Parkia* starch prepared by prehydrolyzed enzyme (α -amylase and amyloglucosidase) in different time (pH-20, 45, 70, 95 and 120 min) showed that the in vitro Englyst test revealed a proportion of 52.29% slowly digestible starch (SDS) and the resulted with prehydrolyzed digestion an almost constant amount of SDS, although an increase of RDS accompanied a reduction of RS with increasing time of prehydrolysis treatment. Usually, the level of RDS (10.91%) in the African locust bean starches were lower than those reported for pea (18.2-23.8%), lentil (16.0-16.9%) and cultivars of other chickpea (21.5-29.9%) starches [43]. However, the level of SDS (52.29%) was comparable to that of lentil (58.3-62.2%), pea (53.7-59.0%) and other chickpea cultivars (45.7-57.7%). Whereas, the resistant starch of African locust bean starch (33.41%) was found to be much higher than those in the Chung et al. [43] work; Chung et al. [44] reported for pea to be 8.1-12.6%, lentil from 13.0-13.2% and other chickpea cultivars in the range of 8.4-18.4%. SDS content, which is considered a desirable form of dietary starch, was 52.29% for *Parkia* and is much better than those reported previously by Zhang and Hamaker [5]. Furthermore, resistant starch content from the *Parkia* is considered to be of a desirable amount [42]. The differences in the methodology AACC [45] vs. Englyst et al. [27] demonstrated that SDS, RDS and RS levels of African locust bean starches can't be compared with the results of legume starches reported above, due to the time periods of hydrolysis defined for the measurement of SDS, RDS and RS levels.

Generally, digestibility of native starch is influenced by starch source, granule size, amylose/ amylopectin ratio, crystallinity, and amylopectin molecular [29, 40, 43, 44]. SDS, which leads to a slower entry of glucose into the blood stream and a lower glycemic response, is digested completely in the small intestine at a lower rate as compared to RDS, while RS is the starch portion that cannot be digested in the small intestine, but is fermented in the large intestine [31,42]. A moderate postprandial glycemic and insulinemic response of SDS implies that SDS rich foods may provide wide health benefits in reducing common chronic diseases such as obesity, diabetes, and cardiovascular disease through lessening the stress on regulatory systems related to glucose homeostasis [12].

Modifications in processing conditions for *P. biglobosa* starch product exhibited minimal impact on the content of RDS though had specific effect on the SDS and RS content [21]. Results from deduced that amylose is the molecular basis of RS, and amylopectin plays a key role in the structure of SDS and is the main constituent of SDS. SDS and RS significantly indicated that various processing conditions promote the inter-conversion between them. Thus, processing conditions can be changed to effectively control the relative content of SDS and RS in *Parkia* starch products. This methodology may enable process modifications to influence the functional digestibility properties of prepared *Parkia* starch products.

7. PARKIA STARCH APPLICATIONS

As is known to all the plants store carbohydrate in the form of starch as the major reserve for energy. Since the starch is produced in the form of granules in most plants cells and is referred to as native; thus, various sources include cereal, grain, nuts, seeds, leaves, tubers, and root are of different biological origin. As the demand increases in industries various sources including new ones are explored to meet the demand; therefore, *P. biglobosa* can be one of the solutions. Even though more researches are needed for this new source of starch. Starch industrial applications varies from one product to another as it is used as a colloidal, thickener, gelling agent, stabilizer, water retention agent, adhesive and bulking agent [18]. However, the development of value-added *Parkia* starch depends on how thorough knowledge around its structure and functional properties are carried out.

Upon the type of starch and processing conditions of starchy foods applied the starch molecules undergo several physical modifications depending [18, 31] leading to the formation of resistant starch. Attempts to modify RS intake in the product like bread as a mixed diet, care should be taken on optimizing the resistant starch content. Report shows that common flour-based breads contain limited quantities of RS, i.e. below 2% (starch basis) [26, 30] refer to in vitro determinations. Sankhon et al. [39] demonstrated the possibility of application of *P. biglobosa* resistant starch in bread as functional products from wheat flour; which led to formulate and develop functional breads from wheat flours composited with different levels *Parkia* flour. The evaluation of the resistant starch content, nutritional, sensory quality and consumer overall acceptability were also done to the *Parkia* RS effects [39, 42]. Indeed, it was found significant resistant starch content and nutritional quality improvement in the bread. The research of the same authors showed that the addition of 5%, 10% and 15% African locust bean flour resulted in bread with high loaf volume and good overall acceptability [39]. Similarly, the sensory evaluation with the same percentage the *Parkia* flour bread came up as the most acceptable bread [39]. New trend of combination of many nutritional benefits of wheat flour supplemented with African locust bean flour as a functional food may be the way to cater for a set of people who suffer from malnutrition, obesity and diabetes.

8. CONCLUSIONS

It can be concluded that *P. biglobosa* seeds are important sources starch extract using different optimized methods. There is no doubt about it that the different fractions of starch extracted from the African locust beans are of good health benefit compared to more others sources of starch; more than a half proportion of slowly digestible starch in it. The application of resistant starch obtained in replacement of wheat flour in different proportion revealed a functional product with significant improvement in the bread resistant starch content and nutritional quality on addition of *Parkia* flour. The application of resistant starch obtained in replacement of wheat flour in different proportion revealed a functional product with significant improvement in the bread resistant starch content and nutritional quality on addition of *Parkia* flour. Therefore, it is

evidence that fortification in the resistant starch content of bread samples using *Parkia* flour may be proposed solution to those suffering from malnutrition, diabetes and obesity. It is left to food developers to come up with such functional food that combines many nutritional benefits of wheat flour supplemented with *Parkia* flour.

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Authors Contributions: IA: Planed, wrote and managed the manuscript; AS: Edited and reread the manuscript. All authors read and approved the final manuscript.

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